Harmful Algal Blooms: What You Need to Know!

A Primer for Drinking Water and Water-Related Applications

Dan Kroll, The Hach Distinguished Scientist and Director of Advanced Technologies Group, Hach Company

Miles Corcoran, Territorial Manager, OTT Hydromet

Greg Lewis, Senior Scientist, LightDeck Diagnostics

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Q&A Moderator

PRESENTER BIOGRAPHIES

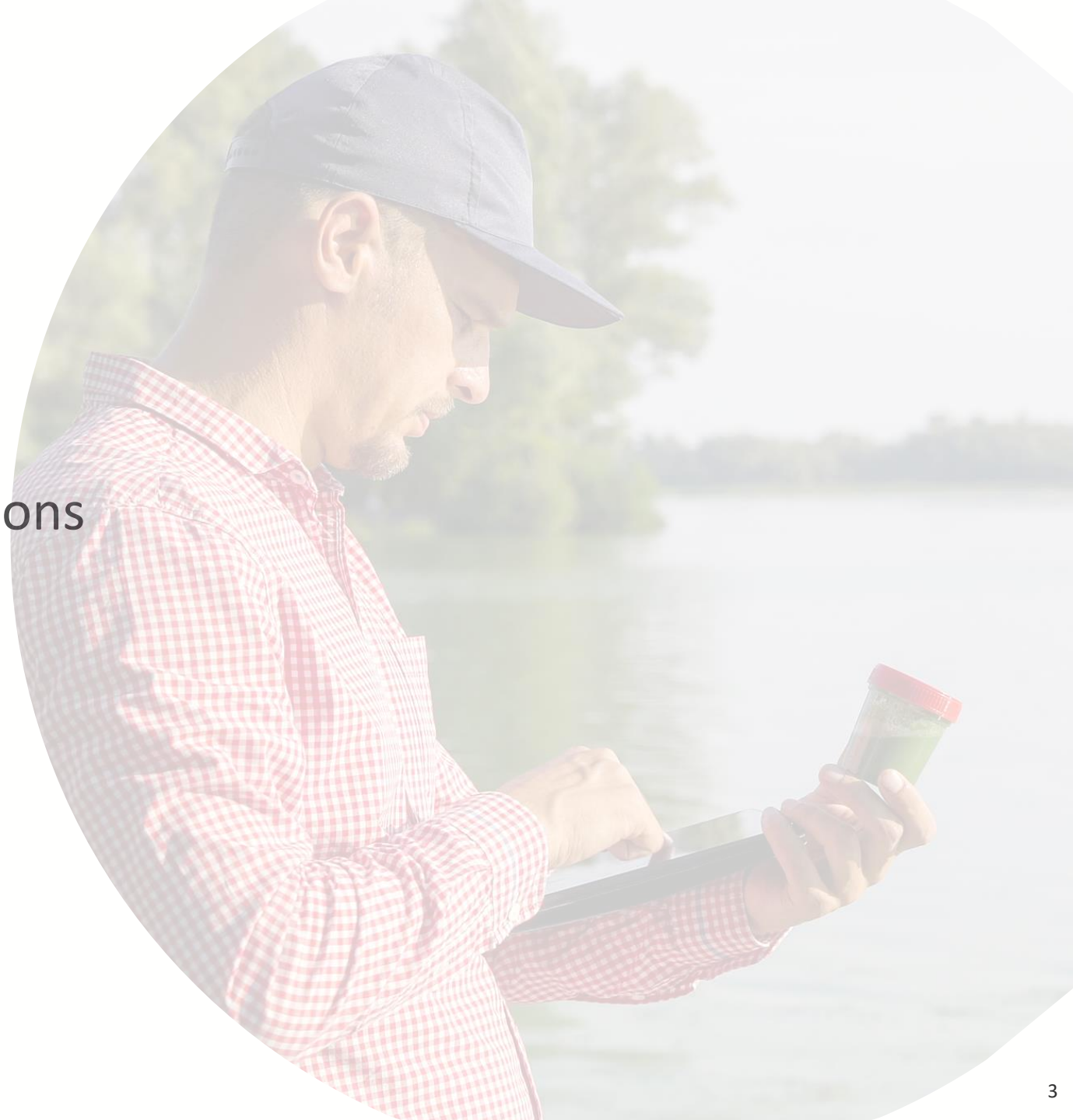
- Dan Kroll is the Hach Distinguished Scientist and Director of Hach's Advanced Technology Group. Dan has worked at Hach for 33 years in a variety of roles. Dan has been the lead researcher on method development projects for the physical, chemical and microbiological quality of water and soils, for which he holds many patents.

- Miles Corcoran is a sales manager for OTT HydroMet, covering numerous Rust Belt states. He has experience designing and managing water quality monitoring networks and has worked on several independent studies focused on blue-green algae detection methods.

- Greg Lewis is a Senior Scientist at LightDeck Diagnostics with extensive experience in assay development and integration into diagnostics platforms.

AGENDA

- Basics of HABs and Cyanotoxins
- EPA Guidance
- HAB Testing and Monitoring Options
- Overview of LightDeck Mini
- Live Q&A with Presenters



BASICS OF HABs & CYANOTOXINS

HARMFUL ALGAL BLOOMS

600% increase in Algal Bloom events reported from 2010-2020[1]

Over $1.1B spent by 22 U.S. states from 2010-Present[2]

Impact is likely much, much higher (lost revenue from tourism, fishing, recreation; incidental healthcare and foregone productivity; lower property values; reduced investment and development)

3 years ago, a massive algae bloom in Florida killed 2,000 tons of marine life. It's threatening again

By Arthur Brice, CNN

Updated 10:05 AM ET, Fri June 4, 2021

'It's gross': A summer of red tides piles up 600 tons of dead fish on Florida beaches.

By Elizabeth Djinis

July 21, 2021

"This," proclaimed an editorial in The Tampa Bay Times last week, "is what climate change smells like."

Chile's salmon farms losing up to $800 million from algal bloom

By Anthony Esposito MARCH 9, 2016 / 8:06 PM /

Surge of algae kills millions of salmon in Norway

By Reuters Staff MAY 22, 2019 / 5:03 AM

Algal blooms will cost the Lake Erie economy $272M a year over a 30-year period if left alone

Angelica Haggert · CBC News · Posted: Jul 24, 2019 4:00 AM ET | Last Updated: July 24, 2019

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Algal Bloom events are increasing, damages are rising

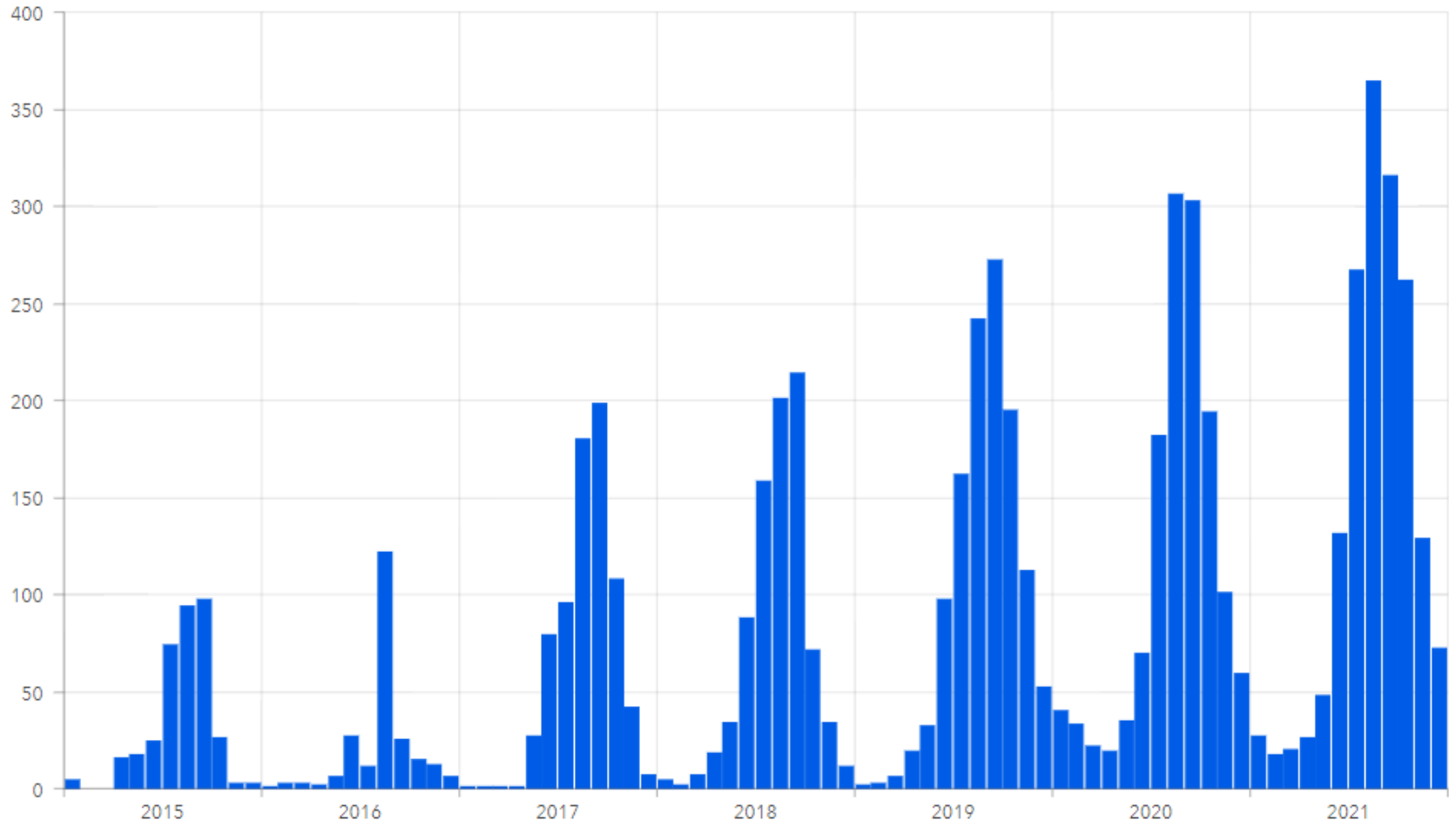
REAL WORLD EFFECTS OF HABS

Toledo, OH 2014

Hundreds of Thousands Without Water In Toledo, Ohio, ABC News, 3 Aug 2014, https://www.youtube.com/watch?v=b8dRDV268nA

HAB which preceded DND order was *milder* than previous seasons[4]

ANNUAL HARMFUL ALGAL BLOOMS, BEACH CLOSURES & ADVISORIES (EPA)



Note: Many states started publicly reporting freshwater HABs advisories since the EPA published its Drinking Water Health Advisories for two cyanotoxins, microcystins and cylindrospermopsin, in 2015.

Source (5): EPA, https://storymaps.arcgis.com/stories/d4a87e6cdfd44d6ea7b97477969cb1dd

HAB Events increasing (increased reporting + increased prevalence)

HARMFUL ALGAL BLOOMS

Why the rise in HAB event reports?

-Rainwater runoff brings superabundance of nutrient (phosphorus, nitrogen from irrigation runoff, sewage, various wastes)
-Rising water temperatures
-Sunlight exposure
-Slow water velocity/mixing

Cyanobacteria—aka Blue-Green Algae (BGA)—is not algae!

Both in fresh and saltwater bodies (e.g., Lake Erie v. Florida's "Red Tide")

Can float, hang suspended in the water column, or sink to the sediment

Bloom decay creates eutrophic/hypoxic conditions (killing flora and fauna)

Dozens of unique cyanobacteria, not all produce cyanotoxins (mechanism not well understood)

Those that release toxins, do so primarily during/after cell death or lysis (disintegration)

-can leach for months after the living bloom is gone
-cannot tell by looking at, smelling, or tasting contaminated water whether it is toxic or not

Nutrients and warmth drive HABs; cannot ID by sight/smell/taste

CYANOTOXINS

HEPATOTOXINS (symptoms: nausea, vomiting, diarrhea, inflammation, kidney damage)

Microystin (MC)

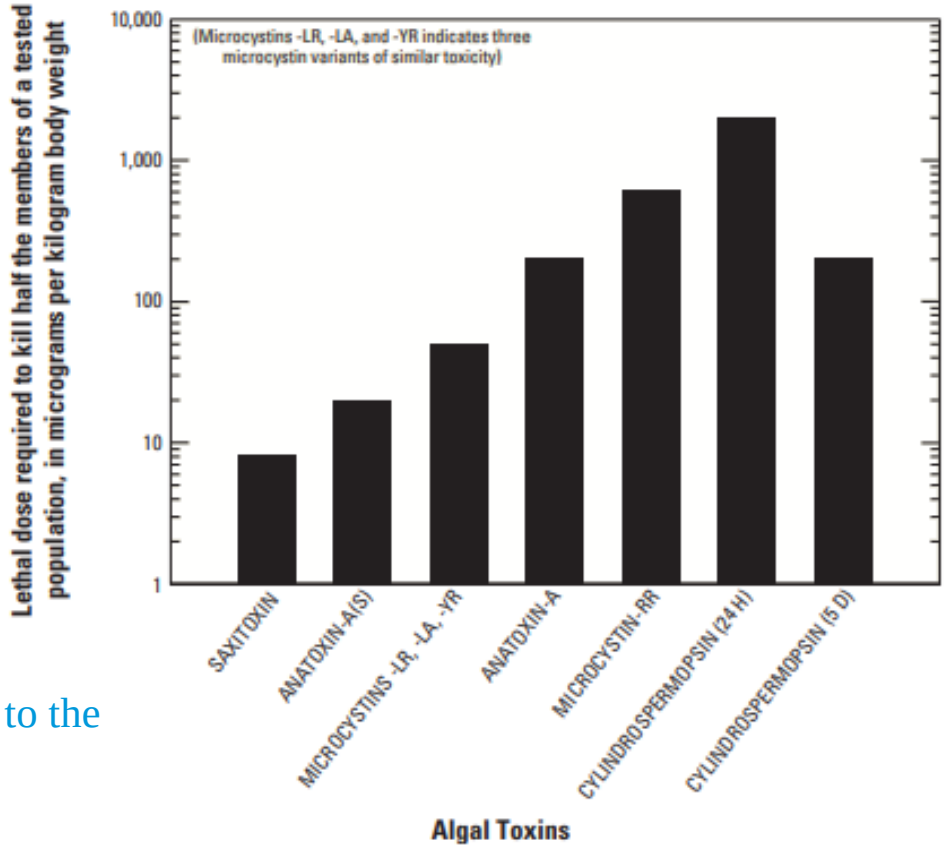
-Most common cyanobacteria

-Too few studies to formally declare as carcinogenic

-5,000-11,600 µg/kg body weight causes liver damage i.e., 2 mg in 10 kg child[7]

Cylindrospermopsin (CYN)

Used to be rare, now observed with increasing frequency



NEUROTOXINS (symptoms: tingling, numbness, slurring words, paralysis)

Anatoxin-A (AN-A)

Saxitoxin (STX)

-Family of Paralytic Shellfish Toxins (used by CIA as a replacement to the WWII cyanide pill)

Cyanotoxins can cause severe liver, kidney and nervous system issues

EPA GUIDANCE

EPA GUIDANCE

No current Federal Drinking Water Regulation that mandates cynanotoxin monitoring or treatment

However,

1) 2016-The Contaminant Candidate List within the EPA Unregulated Contaminant Monitoring Rule provided drinking water health advisories (e.g. for young children, > 0.3 µg/L for microcystins and >0.7 µg/L for cylindrospermopsin)[8]

2) 2019- EPA publishes "Human Health Recreational Ambient Water Quality Criteria or Swimming Advisories"[9] established recommended limits for swimming (MC > 8 µg/L, CYN > 15 µg/L) or general recreation (3+ exceedances in a season (during three separate 10-day testing periods) for more than one year to be considered a body of concern)

EPA Approved Analytical Methods[10]:

Method 544 (for MC and NOD)
Method 545 (for CYN and Anatoxin)
Method 546 (ADDA-ELISA method for Total MC)

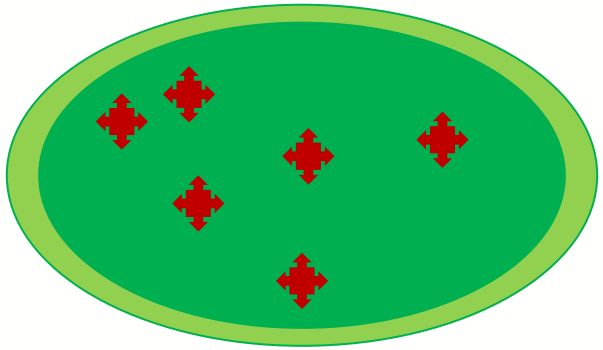
US States have adopted various approaches to monitoring and treatment:

States	Action on HA?	Monitoring required?	Intend to collect data?	Written guidance complete, or in development?
OH, RI	Yes	Yes	Yes	Yes
MD	Yes	No	Yes	Yes
AL, CO, CT, IL, KS, MA, ME, NH, OR, VT	No	No	Yes	Yes
SC	Yes	No	Yes	No
CA, WI	No	No	No	Yes
AR, IA, UT	No	No	Yes	No
AK, AZ, DE, FL, HI, MN, MT, NC, NM, NV, OK, PA	No	No	No	No
GA, ID, IN, KY, LA, MI, MS, NE, ND, SD, TN, VA, WA, WV	No algal toxin expert was reached.			
MO, NJ, NY, TX, WY	Currently reviewing or developing their approach to addressing cyanotoxins in drinking water.			

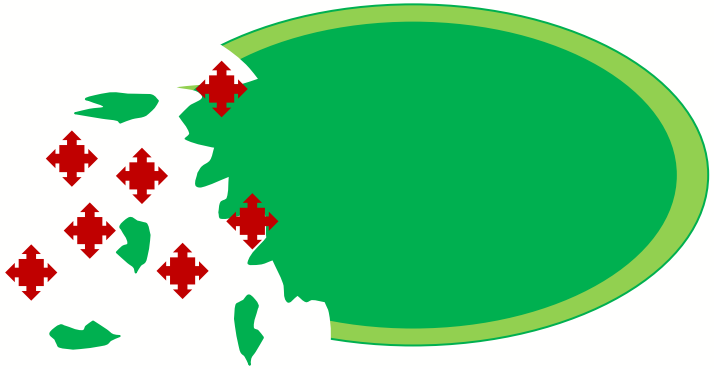
Source (11) "Cyanotoxins in US Drinking Water: Occurrence, Case Studies and State Approaches to Regulation," AWWA, Sep. 2016.

TREATMENT, MANAGEMENT, and PLANNING

CYANOTOXINS—LOCATION MATTERS!



Intracellular Toxins
Cells are Intact



Extracellular Toxins
Cells are Lysed

Note: modified from schematics by Eric C. Wert, Ph.D, Southern Nevada Water Authority

EPA: "Applying the wrong treatment process at a specific state in treatment could damage cyanobacteria cells and result in the release rather than removal of cyanotoxins."

Treatment choices should be intentional and proactively decided

CYANOTOXIN TREATMENT AND MANAGEMENT

	Treatment Method	Relative Effectiveness	Tradeoffs/Considerations
Cyanobacteria Removal (Cells Intact)	Pre-Treatment Oxidation	+	Can lyse cells (such as copper sulfate at intake); assessing minimum dosing strength is paramount
	Coagulation/Sedimentation/Flocculation	++	Sludge must be disposed often; supernant cannot be returned
	Membrane	+++	Biofouling causes decrease in flux
	Flotation (Dissolved Air Flotation) and Skimming	++	Takes advantage of many buoyant variants
Cyanotoxin Removal (Dissolved)	Boiling	---	No Effect! Can also worsen problem because concentration occurs
	Membrane	++	Varies greatly on system attributes, effective on MC; RO usually effective on MC and CYN
	Potassium Permanganate	+/-	Effective on MC and AN-A; Not Effective at STX; Unknown effect on CYN
	Ozone	++	Great for MC, AN-A, CYN. Not effective on STX
	Chloramines	-	No Effective
	Chlorine Dioxide	-	Dose needed is too high for DW treatment
	Free Chlorine	+	Effective if pH<8 (MC); Works for CYN and STX, not AN-A
	Ultraviolet	+/-	Effective when paired with ozone or hydrogen peroxide on AN-A, CYN, and MC.
	Activated Carbon Adsorption	+	For both Powdered and Granular activated carbon, effectiveness is dependent on carbon type, pore size, toxin-type, etc. but they do appear effective on MC and likely for other toxins.

Adapted and expanded from EPA Report-810F11001 Cyanobacteria & Cyanotoxins: Information for Drinking Water Systems, June 2019

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Treatment methods entail significant tradeoffs in cost, effectiveness

HAB RESPONSE PLANNING

Make a plan

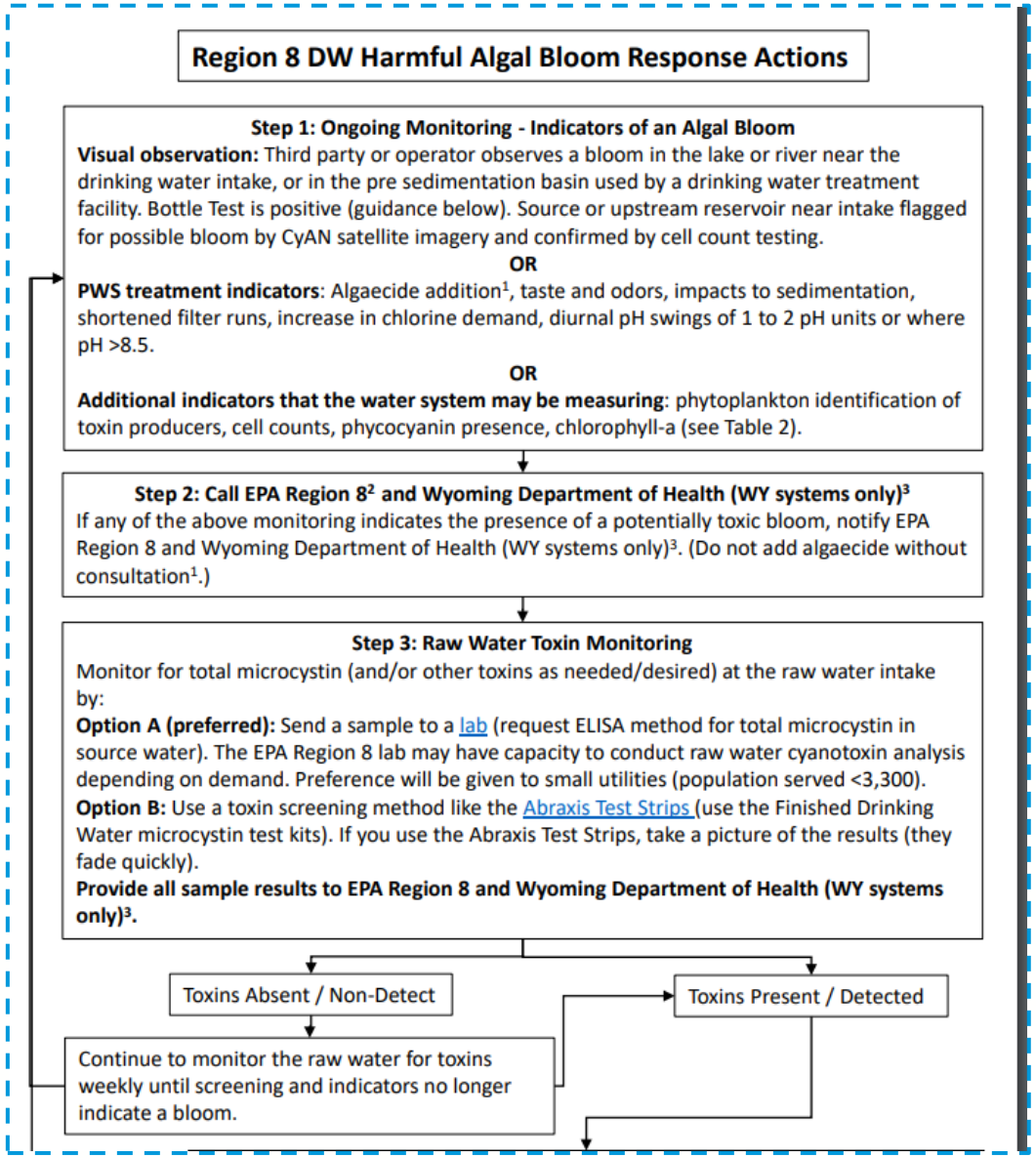
Detail what actions should be taken from the time a bloom is visible

Make a decision tree so everyone knows what to do

Include necessary diagnostic and treatment steps

Don't forget guidance about what not to do

e.g., don't add algaecide or oxidant during bloom without consultation



Region 8 DW Harmful Algal Bloom Response Actions

Step 1: Ongoing Monitoring - Indicators of an Algal Bloom

Visual observation: Third party or operator observes a bloom in the lake or river near the drinking water intake, or in the pre sedimentation basin used by a drinking water treatment facility. Bottle Test is positive (guidance below). Source or upstream reservoir near intake flagged for possible bloom by CyAN satellite imagery and confirmed by cell count testing.

OR

PWS treatment indicators: Algaecide addition[1], taste and odors, impacts to sedimentation, shortened filter runs, increase in chlorine demand, diurnal pH swings of 1 to 2 pH units or where pH >8.5.

OR

Additional indicators that the water system may be measuring: phytoplankton identification of toxin producers, cell counts, phycocyanin presence, chlorophyll-a (see Table 2).

Step 2: Call EPA Region 8[2] and Wyoming Department of Health (WY systems only)[3]

If any of the above monitoring indicates the presence of a potentially toxic bloom, notify EPA Region 8 and Wyoming Department of Health (WY systems only)[3]. (Do not add algaecide without consultation[1].)

Step 3: Raw Water Toxin Monitoring

Monitor for total microcystin (and/or other toxins as needed/desired) at the raw water intake by:

Option A (preferred): Send a sample to a lab (request ELISA method for total microcystin in source water). The EPA Region 8 lab may have capacity to conduct raw water cyanotoxin analysis depending on demand. Preference will be given to small utilities (population served <3,300).

Option B: Use a toxin screening method like the Abraxis Test Strips (use the Finished Drinking Water microcystin test kits). If you use the Abraxis Test Strips, take a picture of the results (they fade quickly).

Provide all sample results to EPA Region 8 and Wyoming Department of Health (WY systems only)[3].

Toxins Absent / Non-Detect

Toxins Present / Detected

Continue to monitor the raw water for toxins weekly until screening and indicators no longer indicate a bloom.

Example response flowchart for Region 8, available at https://www.epa.gov/sites/default/files/2016-06/documents/hab_response_strategy.pdf

Time is of the essence in treating HABs, states share lessons learned

EXAMPLE OF BLOOM SEVERITY CRITERIA AND ACTION THRESHOLDS

Severity Criteria, e.g.

If a PWS is already routinely analyzing for the parameters below, then the severity of the bloom can be classified as:

Minor bloom (meets any of the following)

- **Cyanobacteria cell count (or phycocyanin equivalents[2]) 4,000 to 10,000 cells/ml**
- **Biovolume 0.4 to 1 mm^3/L**
- **Chlorophyll a 2 to 5 ppb**
- **Some visual evidence of a bloom (blooms may not be visually apparent at the surface)**

Moderate bloom (meets any of the following)

- **Cyanobacteria cell count (or phycocyanin equivalents[2]) 10,000 to 100,000 cells/ml**
- **Biovolume 1 to 10 mm^3/L**
- **Chlorophyll a 5 to 50 ppb**
- **Bloom is visible throughout the water column**

Severe bloom (meets any of the following)

- **Cyanobacteria cell count (or phycocyanin equivalents[2]) >100,000 cells/ml**
- **Biovolume > 10 mm^3/L**
- **Chlorophyll a >50 ppb**
- **Algae mat is present and/or significant concentration of cells are visible throughout the water column**
- **Presence of cyanotoxins, as indicated by test kit or laboratory analyses**

Action Level Thresholds, e.g.

Cyanotoxin thresholds and analytical methods

Type of notice	Total Microcystins[2]	Cylindrospermopsin	Anatoxin–a[1]	Total Saxitoxins[1,2]
Do not Drink: children under 6 and sensitive populations[3]	0.3 ppb (EPA Health Advisory value)	0.7 ppb (EPA Health Advisory value)	20 ppb (Ohio Health Advisory value)	0.2 ppb (Ohio Health Advisory value)
Do not Drink: Children 6 and older & adults	1.6 ppb (EPA Health Advisory value)	3.0 ppb (EPA Health Advisory value)	20 ppb (Ohio Health Advisory value)	0.2 ppb (Ohio Health Advisory value)
Do not use[4]	20 ppb	20 ppb	300 ppb	3 ppb
Test Strip Monitoring	Abraxis dip strips[5]	Abraxis dip strips[5]	Abraxis dip strips[5]	When available
Toxin Monitoring and Repeat Sampling	ELISA-ADDA and/or LC-MS/MS[6]	ELISA and/or LC-MS/MS	ELISA and/or LC-MS/MS	ELISA[7] and/or LC-MS/MS

Source: Ohio EPA PWS HAB Response Strategy, https://www.epa.gov/sites/default/files/2016-06/documents/hab_response_strategy.pdf

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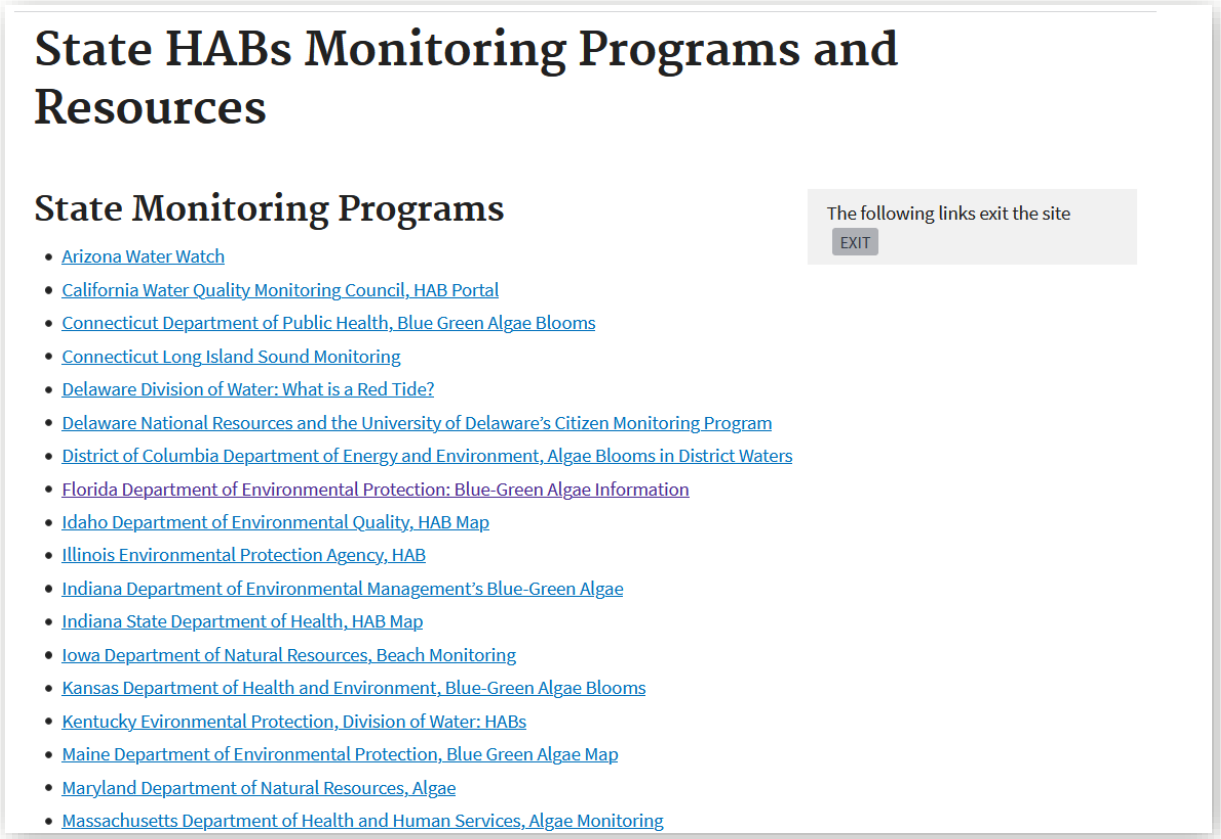
Actions should be based in decision criteria and action/trigger levels

State HAB Monitoring Programs

United States Environmental Protection Agency



State HABs Monitoring Programs and Resources

State Monitoring Programs

The following links exit the site
EXIT

- Arizona Water Watch
- California Water Quality Monitoring Council, HAB Portal
- Connecticut Department of Public Health, Blue Green Algae Blooms
- Connecticut Long Island Sound Monitoring
- Delaware Division of Water: What is a Red Tide?
- Delaware National Resources and the University of Delaware's Citizen Monitoring Program
- District of Columbia Department of Energy and Environment, Algae Blooms in District Waters
- Florida Department of Environmental Protection: Blue-Green Algae Information
- Idaho Department of Environmental Quality, HAB Map
- Illinois Environmental Protection Agency, HAB
- Indiana Department of Environmental Management's Blue-Green Algae
- Indiana State Department of Health, HAB Map
- Iowa Department of Natural Resources, Beach Monitoring
- Kansas Department of Health and Environment, Blue-Green Algae Blooms
- Kentucky Evironmental Protection, Division of Water: HABs
- Maine Department of Environmental Protection, Blue Green Algae Map
- Maryland Department of Natural Resources, Algae
- Massachusetts Department of Health and Human Services, Algae Monitoring

Source: EPA website - //www.epa.gov/cyanohabs/state-habs-monitoring-programs-and-resources

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The EPA has consolidated monitoring resources (learn best practices!)

Communication Tools and Resources

United States Environmental Protection Agency

Drinking Water Cyanotoxin Risk Communication Toolbox – Templates

Both Word and PDF versions are available below.

- Drinking Water Advisory - Everyone (1 pg, 299 K)
- Drinking Water Advisory - Vulnerable Populations (2 pp, 438 K)
- Drinking Water Advisory - Advisory Lifted (1 pg, 5 MB)
- Press Release - Everyone (1 pg, 5 MB)
- Press Release - Vulnerable Populations (1 pg, 5 MB)
- Press Release - Advisory Lifted (1 pg, 5 MB)
- Social Media - Everyone (2 pp, 10 MB)
- Social Media - Vulnerable Populations (2 pp, 6 MB)
- Social Media - Advisory Lifted (2 pp, 285 K)
- Public Messaging (4 pp, 2 MB)

Source: EPA website - https://www.epa.gov/ground-water-and-drinking-water/drinking-water-cyanotoxin-risk-communication-toolbox-templates

HACH LIGHTDECK MINI OTT HydroMet

BASICS of LIGHTDECK

LIGHTDECK MINI ALGAL TOXIN ANALYZER

Automated, fluorescence-based analysis system for rapid quantitative measurement (excitation at 635-645nm and detection at 655-720nm). Results in 10 minutes.

Simultaneously tests for:

- Microcystins (typical range: 0.5-5µg/L)
- Cylindrospermopsin (typical range: 0.7-3µg/L)

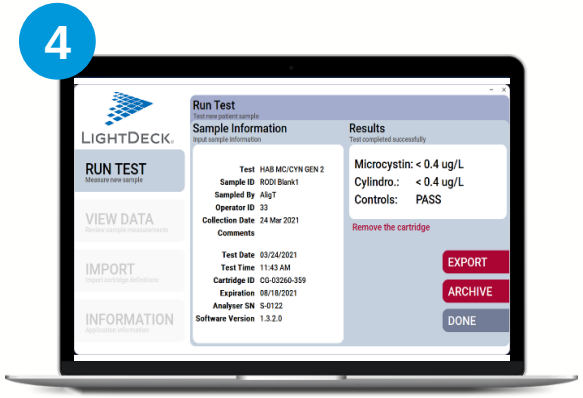
- Useable life: >10,000 tests
- Platform is expanding
  - Anatoxin-a (under development)
  - Saxitoxin tests (under development)
- Advantages: low-cost tests with quantitative, not qualitative results (test-strip based tests are more subjective); test results don't fade

HACH® LIGHTDECK® MINI OTT HydroMet

One test for two major toxins for $27 per test with results in 10 minutes

HAB TOXIN SYSTEM: WORKFLOW

1. Sample added to a tube containing dried reagent and is thoroughly mixed
2. 100 µl of sample/reagent mix is then loaded into test cartridge
3. Loaded test cartridge is then placed in testing system
4. Quantitative algal toxin concentrations are displayed in just 10 minutes
    - *1 pipette and 30 pipette tips included with LightDeck MINI; additional pipettes and pipette tips sold separately*



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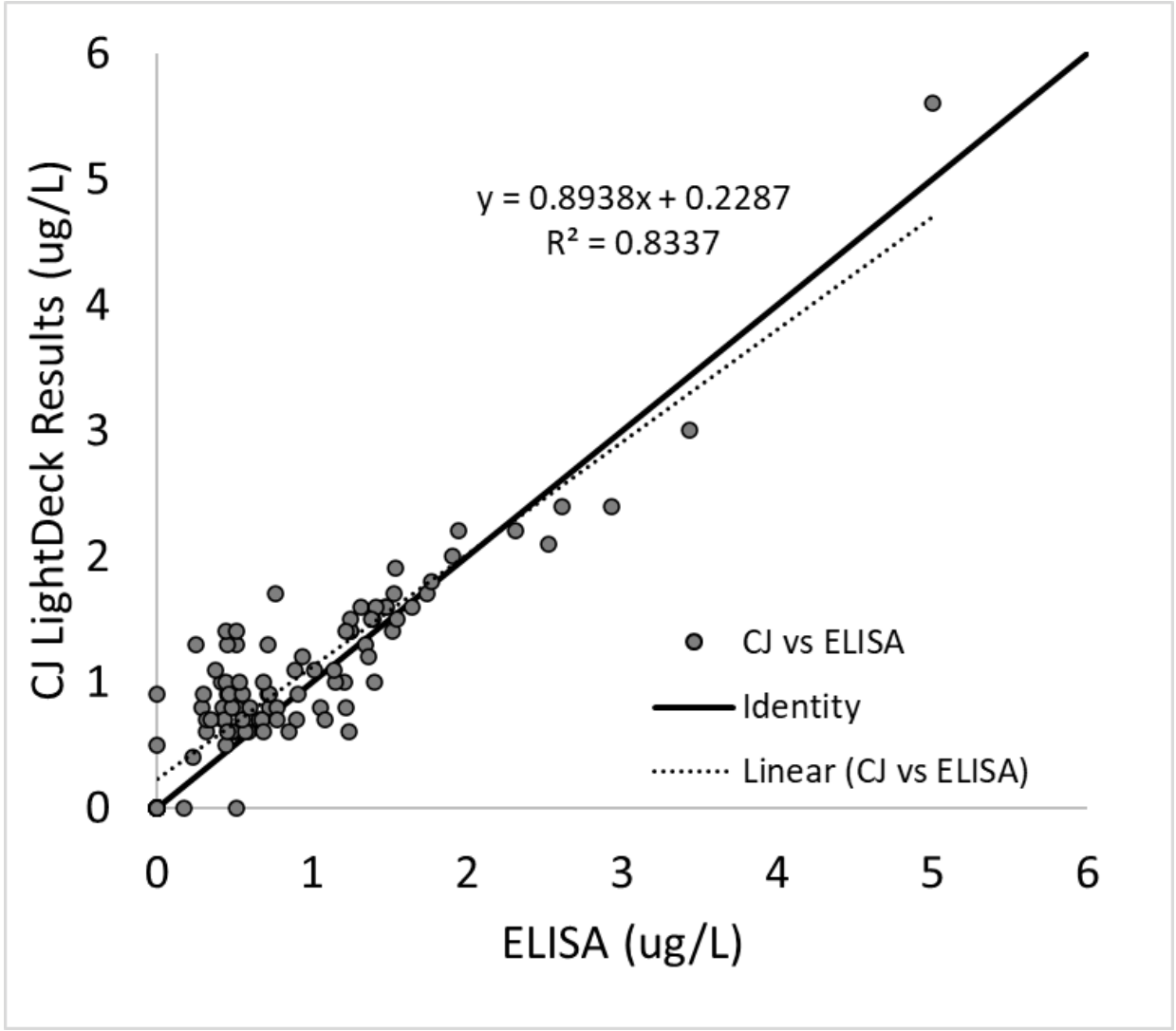
Baseline = you don't know what's abnormal until you know what's normal

IN THE FIELD: MICROCYSTINS AND NODULARINS

- Samples collected and analyzed at Ohio State University, Stone Laboratory



LightDeck MINI shows good correlation with current ELISA methods for microcystins

Comparison of LightDeck and ELISA for Microcystin

- Samples and analysis from Bowling Green State University
- No toxin observed in Sandusky Bay in 2021
  - 42 samples measured:
  - All measured below 0.3 µg/L on ELISA
  - 39 samples measured below detection limit on LightDeck
    - 1 sample measured slightly above detection limit, but not repeated on LightDeck
    - 2 samples measured slightly above detection limit, but repeats were below detection limit on LightDeck

Nontoxic samples from Sandusky Bay measured as expected on LightDeck

CYLINDROSPERMOPSIN COMPARISON WITH ELISA

- Not detected by ELISA or by LightDeck in 2021 MERHAB sampling
- Measurements of cell cultures at Bowling Green State University and LightDeck indicate good correlation between ELISA and LightDeck

[CYN] (µg/L), ELISA	CV (%) ELISA	[CYN] (µg/L), LightDeck	CV (%) LightDeck	Recovery (%)
1.08	3%	1.47	4%	135%
0.98	5%	1.07	14%	108%
0.86	3%	0.80	13%	93%
Average Recovery				**112% ± 19%**

LightDeck correctly measures Cylindrospermopsin cell cultures compared to ELISA

EXPANSION OF FRESHWATER ALGAL TOXIN DETECTION

- Saxitoxins/Paralytic Shellfish Toxins
- Anatoxin-a

LightDeck is expanding freshwater toxin panels to include saxitoxins and anatoxin-a

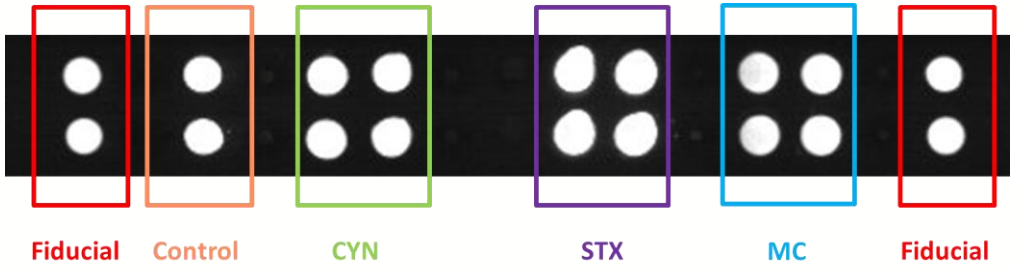
SAXITOXINS/ PARALYTIC SHELLFISH POISONING

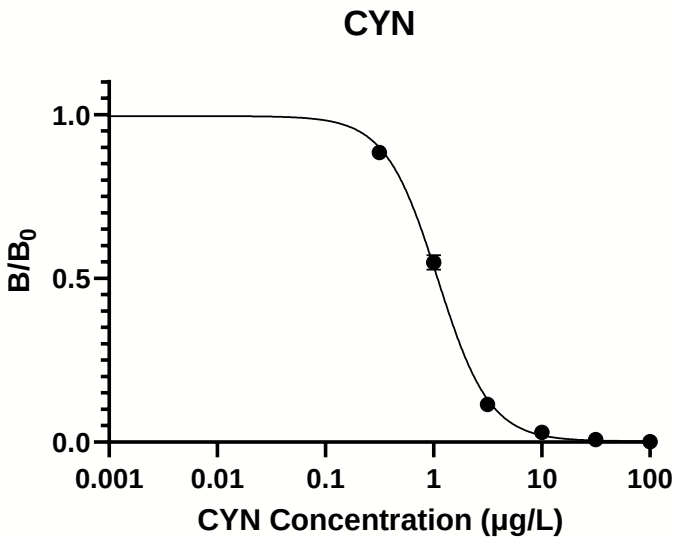
- Correlation between toxicity and cross reactivity
- Sensitivity demonstrated
- Applicable to freshwater, shellfish, and saltwater

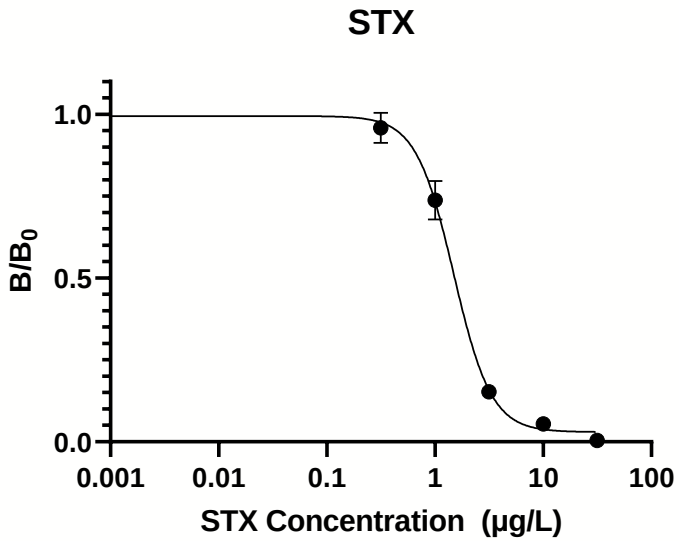
Congener	Toxicity (%)	LightDeck Cross Reactivity (%)
STX	100%	100%
C1&2	1%, 10%	1%
dcGTX2&3	15%, 38%	4%
dcNEO	Not known	3%
dcSTX	51%	17%
GTX1&4	99%, 73%	20%
GTX2&3	36%,64%	58%
GTX5&6	Not known	16%
LyngbiaWollei	Not known	19%
NEO	92%	94%

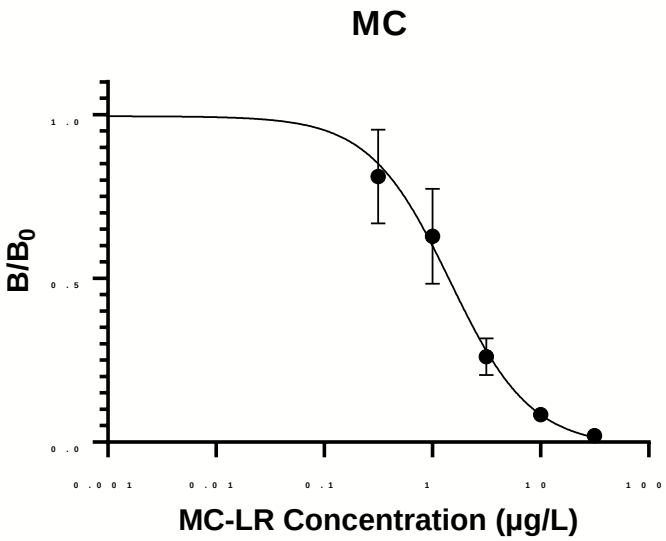
Preliminary saxitoxins cross-reactivity data correlates with congener toxicity

MULTIPLEXED SAXITOXIN ASSAY RESULTS









Triplex assay has demonstrated detection of 3 toxins (MC, CYN, STX) simultaneously

QUESTIONS?

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Alex Rubilar, Global Product Manager, Hach
Q&A Moderator

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